GEOLOGICAL SURVEY OF CANADA.

ALFRED R. C. SELWYN, F.R.S., F.G.S., DIRECTOR.

REPORT

ON

CANADIAN GRAPHITE,

WITH

Special Reference to its Employment as a Refractory Material.

BY

CHRISTIAN HOFFMANN.

and presented with his compliments to Lt. M. Darrell.

MONTREAL:

From the Reports of the Geological Survey of the Dominion of Canada for 1876-77.

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1739

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CHEMICAL CONTRIBUTIONS

TO THE

GEOLOGY OF CANADA,

BY

CHRISTIAN HOFFMANN,

ADDRESSED TO

ALFRED R. C. SELWYN, Esq., F.R.S., F.G.S.,

DIRECTOR OF THE GEOLOGICAL SURVEY OF CANADA.

ON CANADIAN GRAPHITE.

Sir,—I have the honour of herewith submitting to you the results of an investigation into Canadian graphite, undertaken with the object of determining, as far as possible, experimentally the relative value of Canadian graphite, as compared with that from Ceylon, for the manufacture of black-lead crucibles. Object of the investigation.

The first four analyses here given appeared in my last report; as, however, they are intimately connected with some contained in the present one, it has been thought desirable to incorporate them in this latter.

Brief Outline of some of the Methods Employed in the Prosecution of this Investigation.

1. *Determination of the Specific Gravity.*—Sufficient water having been introduced into the specific gravity bottle to thoroughly immerse the specimen of graphite therein contained, the whole was placed under the receiver of an air-pump, and exhaustion gradually proceeded with. The pumping was repeated at intervals, and until bubbles ceased to escape on further exhaustion. The bottle was then removed, and the necessary adjustments having been made, weighed; after which, a portion of the Methods employed in the investigation.

Methods employed in the investigation.

water having been withdrawn, it was again placed under the receiver of the air-pump, etc. etc.

2. *Determination of the Volatile Matter.*—This was effected at a full red-heat, with careful exclusion of atmospheric air.

3. *Determination of the Ash.*—The incineration of the graphite was effected in a platinum boat, inserted in a platinum tube; the latter being heated in a gas combustion furnace; a gentle current of pure, dry oxygen gas being passed through the tube during the operation.

4. *Preparation of the Ash for analysis.*—This was conducted in the same manner as in the preceding determination, with the exception that a much larger boat was employed, and the platinum tube was replaced by one of porcelain.

5. *Determination of the Relative Combustibility of the Graphites.*—The methods employed for determining this depended upon the difference in loss sustained by the specimen under trial as compared with that of the specimen of Ceylon graphite employed as the standard, when ignited under precisely identical conditions.

In the selection of the various graphites it was sought to bring them into the nearest possible accordance as regarded the percentage of ash, for which reason the purest obtainable specimens were in all cases chosen. The percentage of ash in the graphites employed in these experiments was determined after ignition, and the necessary corrections were made for the same in calculating the results. The samples were all ignited previous to use, in order to expel volatile matter, thereby insuring that loss from this source should not be attributed to loss by carbon. The graphite was, in all instances, reduced to the same state of mechanical division. Equal weights of the standard, and the sample under trial, were, in all cases, taken, and due care was observed that the two presented equal surfaces, whether employed in the form of a powder or compressed to that of a cylinder. Although the temperature, as also the strength of the current of oxygen, was very uniformly maintained throughout the course of the experiments, still, no dependence was placed upon this, for which reason the sample under trial was invariably accompanied by a specimen of the graphite employed as the standard.

A. *The Apparatus.*—This consisted of a platinum boat, divided longitudinally into two equal compartments by a strip of platinum foil soldered up the centre. The contour of the boat coincided exactly with that of the interior of the porcelain tube in which it was placed, so that a uniform and tolerably close contact of the sides and bottom of the

boat with the tube was ensured. The porcelain tube was heated in a gas combustion furnace.

Methods employed in the investigation.

B. *Preparation of the Graphite.*—All the samples of graphite were reduced to the same degree of fineness. In order to ensure the greatest practicable uniformity in this respect, they were sized by being placed first upon a sieve of sixty holes to the linear inch, that which passed through being afterwards placed upon a sieve of sixty-six holes to the linear inch, the portion remaining on the latter constituting the material employed in the following experiments.

C. *Manner of Conducting the Experiments.*—Method I. The graphite was in the form of powder; all the samples were strongly ignited previous to their employment. Having taken the weight of the platinum boat, a portion of the graphite employed as the standard was introduced into the left compartment and the boat weighed, after which an equal quantity of the graphite under trial was weighed off into the right compartment. The samples having been carefully adjusted so as to present, as near as possible, equal surfaces, the boat was introduced into the strongly-headed porcelain tube, through which a gentle current of pure, dry oxygen gas was now passed. At the expiration of such time as sufficed for the burning off of about half of either of the specimens, the boat was withdrawn and weighed. This weight, substracted from the weight of the boat prior to insertion, gave the total loss. The residual graphite in the right compartment having been carefully removed, the weight of the boat was again noted; this weight subtracted from the weight of the boat, after inserting the graphite in the left compartment, gave the loss upon the sample therein contained, which loss, subtracted from the total loss, gave, by difference, the loss sustained by the sample contained in the right compartment. In making the control experiment, the position of the samples was reversed; that is to say, the graphite employed as the standard was, on this occasion, introduced into the right compartment, whilst the graphite under trial now occupied the left. By this arrangement, also, the loss by difference fell alternately upon the specimen employed as standard, and the one under trial.

Method II. The graphite was in the form of cylinders. The various samples having been strongly ignited, were compressed in a steel mould into a compact cylindrical form. In preparing the cylinders it was sought to employ, as near as possible, the same pressure in all cases. As, however, there was a possibility of a slight variation occurring in this respect, the further precaution was taken of weighing out equal

quantities of the various graphites, and compressing them into cylinders of equal length. The cylinders, which weighed, as near as possible, two grammes each, were twenty-six millimetres in length and seven millimetres in diameter. They had a beautifully smooth glassy surface, and were perfectly firm. The experiment was conducted in a precisely similar manner to that described under method 1. A cylinder of the standard graphite invariably accompanied a cylinder of the specimen under trial, being laid abreast of each other—one in either compartment.

Canadian Graphite—Disseminated Graphite.

1. *Disseminated Graphite.*

From the twenty-eighth lot of the sixth range of Buckingham. The property of the Montreal Plumbago Mining Company. An exceedingly important deposit. The specimen examined was regarded as a fair average of one of the largest and most extensively worked beds of disseminated graphite in this whole section. The bed averages eight feet, and runs across the whole of this lot and into lot twenty-seven in the seventh range, (the property of the Buckingham Mining Company),—authority, Mr. H. G. Vennor.

Analysis of "Disseminated graphite" from Buckingham.

The graphite, which occurs in scales, is so closely and evenly distributed through the rock as almost entirely to mask its nature. The mineral contains some calcite; the presence of a small quantity of pyrrhotite or magnetic pyrites, was also established. The powdered rock is attacked by hydrochloric acid; this acid, with the aid of heat, dissolved out 17·539 per cent.; the solution was found to contain:

Silica	very small quantity.	Lime	large quantity.
Alumina	very large "	Magnesia	small "
Iron	rather large "	Cobalt	trace.
Manganese	small "	Alkalies	not sought for.

The rock contains:

Graphite	27·518
Rock matter, soluble in hydrochloric acid	17·539
Rock matter, insoluble in hydrochloric acid	54·899
Hygroscopic water	0·044
	100·000

2. *Disseminated Graphite.*

Analyses of "Disseminated graphite" from Buckingham.

From the twenty-second lot of the sixth range of Buckingham. The property of the Buckingham Mining Company. Several important beds of disseminated graphite occur towards the front of this lot. They have as yet only been uncovered. The specimen examined was considered a fair average of one of the most important beds.—Authority, Mr. H. G. Vennor.

The graphite, which occurs in scales, is evenly distributed through the rock; the latter was very much decomposed, and coloured brownish-yellow to reddish-brown from the presence of ferric hydrate. The rock contained no calcite; a small quantity of pyrrhotite was, however, shown to be present. Hydrochloric acid, with the aid of heat, dissolved out from the powdered rock 19·467 per cent.; the solution was found to contain:

Silica	very small quantity.	Lime	large quantity.
Alumina	large "	Magnesia	" "
Iron	" "	Cobalt	trace.
Manganese	small "	Alkalies	not sought for.

The rock contains:

Graphite	22·385
Rock matter, soluble in hydrochloric acid	19·467
Rock matter, insoluble in hydrochloric acid	56·408
Hygroscopic water	1·740
	100·000

3. *Disseminated Graphite.*

From the twentieth lot of the eighth range of Buckingham. The property of the Dominion of Canada Plumbago Company. From a large bed of disseminated graphite, probably of considerable extent. The specimen examined was considered a fair average.—Authority, Mr. H. G. Vennor.

The graphite is pretty evenly disseminated in scales throughout the rock. The latter contains some calcite, as also small quantities of pyrrhotite. The powdered mineral is freely attacked by hydrochloric acid, which, with the aid of heat, dissolved out 21·285 per cent.; the solution was found to contain:

Analyses of "Disseminated graphite" from Buckingham.

Silica	very small quantity.	Lime	large quantity.
Alumina	very large "	Magnesia	moderate quantity.
Iron	large "	Cobalt	trace.
Manganese	small "	Alkalies	not sought for.

The rock contains:

Graphite	23·798
Rock matter, soluble in hydrochloric acid	21·285
Rock matter, insoluble in hydrochloric acid	53·741
Hygroscopic water	1·176
	100·000

4. *Disseminated Graphite.*

From the twenty-third lot of the sixth range of Buckingham. The property of the Buckingham Mining Company.

This deposit has been traced through into the seventh range. It would appear to be a bed whose position is conformable to the stratification of the beds of disseminated graphite, and connecting with the true fissure veins which cross these beds. The rock consists of quartz and a feldspar, and is traversed by more or less disconnected lenticular layers of a twisted, fibrous graphite. These layers, which vary greatly in thickness, may, perhaps, justly be regarded as interstratified veins. As yet the ground has only been uncovered, but it is considered probable that the rock, for a transverse measurement of some fifteen to twenty feet would yield largely. The specimen examined was considered a pretty fair average.—Authority, Mr. H. G. Vennor.

The rock contained no calcite; the presence of a small quantity of pyrrhotine was, however, established The powdered mineral was very little acted upon by hydrochloric acid; this acid, by the aid of heat, dissolved out only 2·475 per cent.; the solution was found to contain:

Silica	trace.	Lime	small quantity.
Alumina	small quantity.	Magnesia	" "
Iron	" "	Cobalt	trace.
Manganese	very small quantity.	Alkalies	not sought for.

The rock contains:

Graphite	30·516
Rock matter, soluble in hydrochloric acid	2·475
Rock matter, insoluble in hydrochloric acid	66·874
Hygroscopic water	0·135
	100·000

Mode of extracting the graphite from the "Disseminated graphite."

The following is a brief outline of the method hitherto employed in the separation of the graphite from the material in which it is disseminated. It is the one which was adopted at the Lochaber Plumbago Company's works, and more recently, at the Canada Plumbago Company's works. The little information that could be obtained on this subject differs but in few particulars from the description of the process given by Sir W. E. Logan.* It will be seen that the dressing is based entirely upon mechanical principles.

The works include a stamping mill, round buddles, slime pits, etc., etc. The crude ore is stamped fine in water and then put through the buddles, by which the graphite and the rock matter associated with it are separated from one another according to their specific gravities. The former, being the lighest, gradually reaches the outer ring; while the latter, being heavier, remains in the centre. The graphite is, subsequently, charged into a reverberatory furnace and ultimately passed through the bolter; the gauze of which is of various degrees of fineness, according to the size required in each special grade.

Canadian Graphite—Dressed Graphite.

The following seven examples of "dressed graphite" were received from the works of the Dominion of Canada Plumbago Company for the special purpose of examination. The material from which they were prepared was taken from a bed of "disseminated graphite," occurring on the twentieth lot of the eighth range of Buckingham. The results of the analysis of what was regarded as a fair average sample of this bed will be found given under analysis 3. The "A 0" grade was in the form of an impalpable powder, and from this they uniformly increased in size of flake up to "A 6" grade, which was the coarsest.

5. *Dressed Graphite.*

Analyses of "Dressed graphite."

Grade known as "A 0."—Designed employment: electrotyping, pencils. After drying at 100° C. this specimen was found to contain:

Ash per cent.....	17·682.

Colour of the ash light-brownish-red; a portion placed upon moist turmeric paper manifested an alkaline reaction.

Hydrochloric acid dissolved out of this graphite a considerable quantity of iron, alumina, lime and magnesia, especially of the first named; no other constituents were sought for. This graphite contains some calcite.

* Reports of the Geological Survey, 1863–66.

6. *Dressed Graphite.*

Analyses of "Dressed graphite."

Grade known as "A 1."—Designed employment: lubricating, pencils, pianos.

After drying at 100° C. this specimen was found to contain:

Ash per cent..... 5·143.

Colour of the ash reddish-brown; a portion placed on moist turmeric paper manifested an alkaline reaction. The ash contained a little mica.

Hydrochloric acid dissolved out of this graphite a considerable quantity of iron, alumina, lime and magnesia, especially of the first named; no other constituents were sought for. This graphite contains some calcite.

7. *Dressed Graphite.*

Grade known as "A 2."—Designed employment: lubricating, pencils, paints, powder, shot.

After drying at 100° C. this specimen was found to contain:

Ash per cent..... 10·737

Colour of the ash reddish-brown; a portion placed on moist turmeric paper manifested an alkaline reaction. The ash contained a little mica.

Hydrochloric acid dissolved out of this graphite a considerable quantity of iron, alumina, lime and magnesia, especially of the first named; no other constituents were sought for. This graphite contained some calcite.

8. *Dressed Graphite.*

Grade known as "A 3."—Designed employment: crucibles, lubricating.

After drying at 100° C. this specimen was found to contain:

Ash per cent..... 7·645

Colour of the ash reddish-brown; a portion placed on moist turmeric paper manifested an alkaline reaction. The ash contained mica.

Hydrochloric acid dissolved out of this graphite a considerable quantity of iron, alumina, lime and magnesia, especially of the first named; no other constituents were sought for. This graphite contained some calcite.

9. *Dressed Graphite.*

Grade known as "A 4."—Designed employment: crucibles, lubricating.

After drying at 100° C. this specimen was found to contain:

Ash per cent..... 5·696

Analyses of "Dressed graphite."

Colour of the ash reddish-brown; a portion placed on moist turmeric paper manifested an alkaline reaction. The ash contained mica.

Hydrochloric acid dissolved out of this graphite a considerable quantity of iron, alumina, lime and magnesia, especially of the first named; no other constituents were sought for. This graphite contained some calcite.

10. *Dressed Graphite*

Grade known as "A 5."—Designed employment: crucibles, lubricating.

After drying at 100° C. this specimen was found to contain:

Ash per cent..... 4·407

Colour of the ash reddish-brown; a portion placed on moist turmeric paper manifested an alkaline reaction. The ash contained mica.

Hydrochloric acid dissolved out of this graphite a considerable quantity of iron, alumina, lime and magnesia, especially of the first named; no other constituents were sought for. This graphite contained some calcite.

11. *Dressed Graphite.*

Grade known as "A 6." Designed employment: crucibles, lubricating.

After drying at 100° C., this specimen was found to contain:

Ash per cent..... 3·638

Colour of the ash, reddish-brown. A portion placed on moist turmeric paper manifested an alkaline reaction. The ash contained mica.

Hydrochloric acid dissolved out of this graphite a considerable quantity of iron, alumina, lime and magnesia, especially of the first named. No other constituents were sought for. This graphite contained some calcite.

12. *Dressed Graphite.*

This sample was also received from the works of the Dominion of Canada Plumbago Company.

The grade was not specified. It was prepared from material from the same bed of "disseminated graphite" as the preceding samples. The results of its analysis are given, not with the object of showing its degree of purity, but as illustrative of the beneficial results attendant upon the employment of hydrochloric acid in the final stage of preparation of these "dressed graphites."

After drying at 100° C., this specimen was found to contain:

Ash per cent..... 13·152

Analyses of "Dressed graphite."

Colour of the ash, light reddish-brown. A portion placed upon moist turmeric paper manifested an alkaline reaction. The ash contained mica.

A portion of this graphite was digested with hydrochloric acid, which removed a considerable quantity of iron, alumina, lime and magnesia, a little silica, and traces of manganese. No other constituents were sought for.

The residual graphite having been carefully washed and dried at 100° C., was found to contain :

Ash per cent..... ..... 6·690

Colour of the ash, white, with a faint reddish tinge. It contained some mica.

An analysis of this ash gave 79·972 per cent. silica. The constituents of the remaining portion, the principal of which appeared to be alumina, lime and magnesia, were not estimated.

On the further purification of "Dressed graphite."

All the foregoing samples of "dressed graphite" contained more or less carbonate of lime and oxide of iron, the presence of which in any graphite, intended for the manufacture of crucibles, is very objectionable. Now, not only are these readily removed by digestion of the graphite with hydrochloric acid, but, as will be seen, so also were other constituents of the foreign mineral matter, so that—taking this particular instance—the graphite, which before treatment contained 13·15 per cent. ash, after treatment was found to contain only 6.69 per cent., a difference of 6·46 per cent. And furthermore, the nature of the ash of the graphite, which had undergone the hydrochloric acid treatment, consisting, as it did, for the greater part, of silica—that is to say, of the 6·69 per cent. ash 5·35 consisted of silica, the balance of 1·34 being composed of alumina, lime, magnesia, etc.,—was such as to warrant the assumption that it would in no wise be prejudicial to the application of the purified graphite for the manufacture of crucibles.

The two following samples of "dressed graphite" were prepared by the Canada Plumbago Company, at present the Montreal Plumbago Mining Company. The material operated on was taken from the bed of "disseminated graphite" occurring on the twenty-eighth lot of the sixth range of Buckingham. The results of the analysis of what was regarded as a very fair average sample of this bed, will be found given under analysis 1.

Analyses of "Dressed graphite."

13. *Dressed Graphite.*

Sample 1. In the form of an almost impalpable powder. Designed employment: electrotyping, pencils.

After drying at 100° C. this specimen was found to contain:

Ash per cent..... 5·374

Colour of the ash reddish-brown, almost brick-red; a portion placed upon moist turmeric paper manifested an alkaline reaction.

A portion of this graphite was digested with hydrochloric acid, which dissolved out a considerable quantity of iron, alumina and lime, and a little magnesia; no other constituents were sought for. This graphite contained some calcite.

The residual graphite having been carefully washed and dried at 100° C, was found to contain:

Ash per cent..... 2·542.

Colour of the ash white, with a faint reddish tinge.

14. *Dressed Graphite.*

Sample 2. In the form of fine scales. The grade was not specified.

After drying at 100° C. this specimen was found to contain:

Ash per cent..... 10·304.

Colour of the ash light-reddish-brown; a portion placed upon moist turmeric paper manifested a slight alkaline reaction. The ash contained mica.

A portion of the graphite was digested with hydrochloric acid; which removed a considerable quantity of iron and alumina, small quantities of lime and magnesia, a small quantity of silica and a trace of manganese; no other constituents were sought for. This graphite contained a small quantity of calcite.

The residual graphite having been carefully washed and dried at 100° C. was found to contain:

Ash per cent..... 5·958.

This ash, which was white, with a very faint reddish tinge, and contained some mica, gave on analysis 74·007 per cent. silica; the alumina, lime and magnesia, and which appeared to be the most predominant constituents of the balance of the ash, were not estimated.

The results of this analysis are given solely for the purpose of further illustrating the advantages resulting from an hydrochloric acid treatment

of these "dressed graphites," as already exemplified by analyses twelve and thirteen. The remarks made in the concluding paragraph under the former of these analyses will—apart from the precise figures—apply with equal force, not only here, and where the figures to be substituted for those there occuring are given, but to all dressed graphites obtained according to the present process from either of the two beds of "disseminated graphite" from which the foregoing samples were prepared.

Canadian Graphite—Vein Graphite.

15. *Vein Graphite, var. Foliated.*

Analyses of vein graphite from Buckingham.

From a vein running through lots twenty-one and twenty-two of the seventh range of Buckingham.

The structure of this graphite was massive, dense, made up of broad and thick laminæ. Colour dark steel-grey. Lustre metallic. Specific gravity 2·2689, (containing 0·147 per cent. ash.) Heated in the closed tube it gave off a little water, but not more than sufficient to form a film.

The specimen contained, here and there, thin seams of foreign mineral matter; apart from this it appeared to be very free from such admixture. The mean percentage of ash, in an average sample of a specimen weighing nearly one kilogramme (rejecting such portions as contained the seams of foreign mineral matter) was found to be 0·195 per cent.

The material employed for analysis was carefully selected; its composition was found to be as follows:—

Carbon	99·675
Ash	0·147
Volatile matter	0·178
	100·000

Colour of the ash, light reddish-brown.

COMPOSITION OF ASH PER CENT.	
Silica	56·080
Alumina	11·120
Sesquioxide of iron	13·270
Sesquioxide of manganese	0·352
Lime	6·800
Magnesia	6·739
Potash	2·197
Soda	2·827
Protoxide of copper	0·660
Protoxide of nickel	0·483
Protosesquioxide of cobalt	0·326
	100·854

Analyses of vein graphite from Buckingham.

As explanatory of the presence of nickel and cobalt in the ash of this graphite, it may be mentioned that the pyrite from veins in the Laurentian rocks has been found, by Dr. T. S. Hunt, to occasionally contain cobalt and nickel, sometimes in large proportions; in the present instance, however, it is more probable that their presence may be referred to pyrrhotite, also, a nickeliferous and cobaltiferous mineral, and which has been shown to be present in the beds of disseminated graphite (analyses 1, 2, 3 and 4) occurring in the same locality. With reference to the presence of copper, Mr. H. G. Vennor informs me that he has, in more than one instance, observed small scales and grains of chalcopyrite in the quartzo-feldspathic gangue of the veins of graphite.

16. *Vein Graphite, var., Columnar.*

From the twenty-seventh lot of the sixth range of Buckingham.

This specimen is stated to have occurred towards the centre of the vein: it had a lenticular shape and contained a core of corresponding form, consisting of orthoclase and calcite, with very small quantities of quartz; the composition of the feldspar will be found given under analysis twenty-five.

Structure of the graphite, compact, columnar; the columnar structure is usually erect, and at right angles to the surface upon which it occurs; in some instances, however, it is curved, as though from pressure. The graphite breaks readily in the direction of the structure into more or less angular aggregates, each aggregate being made up of thin, narrow foliæ of very uniform width. The length of the columns varied in different specimens from about one and a-half to eight centimetres. In this specimen the foreign mineral matter was very evenly distributed through the structure of, and as a film upon the graphite, so that on incineration the residual ash formed a tolerably perfect cast of the fragments employed. Colour of untarnished foliæ, dark steel-grey. Lustre metallic. Specific gravity 2·2679 (containing 1·780 per cent. ash.) Heated in the closed tube gave off a little water, but not more than sufficient to form a film.

The material employed for analysis was carefully selected; its composition was found to be as follows:—

Carbon	97·626
Ash	1·780
Volatile matter	0·594
	100·000

Analyses of vein graphite from Buckingham.

Colour of the ash, light yellowish-grey; a portion placed upon moist turmeric paper manifested a strong alkaline reaction.

A portion of the foreign mineral matter in this graphite consisted of calcite; it may, therefore, be inferred, considering the small amount of water indicated on heating in the closed tube, that the "volatile matter" consisted largely of carbonic acid.

COMPOSITION OF ASH PER CENT.

Silica	45·729
Alumina	10·824
Sesquioxide of iron	1·230
Sesquioxide of manganese	0·467
Lime	34·744
Magnesia	0·952
Potash	0·522
Soda	5·403
	99·871

17. *Vein Graphite, var. Foliated.*

Analyses of vein graphite from Grenville.

From the north-half of the third lot of the second range of the Augmentation of Grenville. An exposure here was at one time mined to a small extent. At the opening of the excavation it showed a thickness of about ten inches, but the pure graphite was found to form a lenticular mass, which appeared to be separated from other masses of the same character by intervals, in which the graphite became intermixed with the limestone. The foregoing from information supplied by Mr. Charles Robb.

The specimen weighed about eight kilogrammes, and was one of great purity. The exposed faces of laminæ had become tarnished with a reddish-brown coloured film; but, apart from this, and the contents of an occasional small fissure, it apparently contained very little foreign matter.

Structure massive, dense, made up of broad and thick laminæ, closely interlocking each other at diverging angles, thus presenting a radiated arrangement, the sides of the vein forming the basal line. Colour, dark steel-grey. Lustre metallic. Specific gravity 2·2714 (containing 0·076 per cent. ash.) Heated in the closed tube this graphite gave off a little water, but not more than sufficient to form a mere film.

The material employed for analysis was carefully selected, and contained no visible foreign matter. Its composition was found to be as follows:—

Analyses of vein graphite from Grenville.

Carbon	99·815
Ash	0·076
Volatile matter	0·109
	100·000

Colour of the ash, light reddish-brown.

COMPOSITION OF ASH PER CENT.

Silica	55·080
Alumina	8·500
Sesquioxide of iron	18·310
Sesquioxide of manganese	0·309
Lime	7·700
Magnesia	2·018
Potash	4·779
Soda	2·969
Protoxide of copper	1·160
Oxides of nickel and cobalt	0·120
	100·945

With regard to the presence of copper, nickel and cobalt in the ash of this graphite, see in this connection remarks made under analysis 15.

18. *Vein Graphite, var. Columnar.*

From lot one of the sixth range of the Augmentation of Grenville. Structure massive, dense, made up of stout, narrow laminæ, interlocking each other at such an angle as to present an almost columnar appearance. In parts, viz., those in closest proximity to the vein rock, this structure was so fine as to appear coarsely fibrous. Colour, dark steel-grey. Lustre metallic. Specific gravity 2·2659 (containing 0·135 per cent. ash.) Heated in the closed tube this graphite gave off a little water, but only sufficient to form a filmy deposition.

This was a very pure specimen of graphite and contained no readily perceptible foreign matter. An analysis showed it to contain :—

Carbon	99·757
Ash	0·135
Volatile matter	0·108
	100·000

Colour of the ash, light reddish-brown.

COMPOSITION OF ASH PER CENT.

Analyses of vein graphite from Grenville.

Silica	60·800
Alumina	10·040
Sesquioxide of iron	16·721
Sesquioxide of manganese	0·869
Lime	4·400
Magnesia	3·877
Potash	1·025
Soda	1·049
Protoxide of copper	1·940
Protoxide of nickel	trace.
Protosesquioxide of cobalt	0·299
	101·020

With regard to the presence of copper, nickel and cobalt in the ash of this graphite, see in this connection remarks made under analysis 15.

The samples of Ceylon and Ticonderoga graphite, the analyses of which here follow, were employed for comparison with the preceding specimens of Canadian graphite, with regard to relative combustibility. For the four samples of the first named, I have much pleasure in acknowledging my obligation to the Messrs. Morgan Brothers, of London, England, the extensive manufacturers of black-lead crucibles.

Ceylon Graphite—Vein Graphite.

19. *Vein Graphite, var. Columnar.*

From Ceylon.

Analyses of vein graphite from Ceylon.

Structure massive, dense, made up of minute laminæ, arranged in such wise as to present a finely fibrous or columnar aspect. Colour dark steel-grey. Lustre of freshly fractured surface sub-metallic, that of worn surfaces bright metallic. Tough. Fracture hackly. When fractured across the structure, a fine granular surface is presented, dull, and blackish-grey in colour. Specific gravity 2·2671 (containing 0·050 per cent. ash.) Heated in the closed tube gave off a little water, but only sufficient to form a film.

This graphite was remarkably free from foreign mineral matter. The following are the results of the analysis of a fair average of a specimen weighing three hundred and eighty-five grammes.

Carbon	99·792
Ash	0·050
Volatile matter	0·158
	100·000

Colour of the ash, very light yellowish-brown.

20. *Vein Graphite, var. Foliated.*

Analyses of vein graphite from Ceylon.

From Ceylon.

Structure massive, dense, made up of thick closely interlocking laminæ. Colour dark steel-grey. Lustre metallic. Specific gravity 2·2664 (containing 0·213 per cent. ash.) Heated in the closed tube gave off a little water, but only sufficient to form a film. The visibly present foreign matter in this graphite occurred as an occasional filmy deposit on the face of laminæ. The material employed for analysis was carefully selected. The analysis gave,

Carbon	99·679
Ash	0·213
Volatile matter	0·108
	100·000

Colour of the ash, light reddish-brown.

21. *Vein Graphite, var. Columnar.*

From Ceylon.

Structure massive, compact, columnar. Colour dark steel-grey. Lustre metallic. Specific gravity 2·2546 (containing 0·283 per cent. ash.) Heated in the closed tube gave off water sufficient to form a beady deposition: the vapour changed the colour of moistened blue litmus paper to red. The foreign mineral matter was very evenly distributed through the structure of this graphite, the composition of which was found to be as follows:—

Carbon	98·817
Ash	0·283
Volatile matter	0·900
	100·000

Colour of the ash, brownish-red: a portion placed on moist turmeric paper manifested an alkaline reaction.

The foreign matter contained in this graphite consisted in part of calcite, as a consequence, the "volatile matter" was composed in part of carbonic acid.

22. *Vein Graphite, var. Foliated.*

From Ceylon.

Structure lamellar, the laminæ being of considerable size. Colour dark-steel grey. Lustre metallic. Specific gravity 2·2484 (containing 0·415 per cent. ash.) Heated in the closed tube gave off a little water, but only sufficient to form a film. At a first glance this appeared to be

Analyses of vein graphite from Ceylon.

a very pure specimen of graphite, but on raising the foliæ it was found to contain, here and there, thin plates of foreign mineral matter.

Its composition was found to be as follows :—

Carbon	99·284
Ash	0·415
Volatile matter	0·301
	100·000

Colour of the ash, light-grey

United States Graphite—Vein Graphite.

23. *Vein Graphite, var. Foliated.*

Analyses of vein graphite from Ticonderoga.

From Ticonderoga, State of New York.

Structure massive, dense, lamellar. Colour dark steel-grey. Lustre metallic. Specific gravity 2·2599 (containing 2·153 per cent. ash). Heated in the closed tube gave off a little water, but not more than sufficient to form a film. The material employed for analysis was carefully selected ; its composition was found to be as follows :—

Carbon	96·656
Ash	2·153
Volatile matter	1·191
	100·000

Colour of the ash, ash-grey ; a portion placed upon moist turmeric paper manifested an alkaline reaction.

The foreign mineral matter contained in this graphite consisted in part of calcite; it may, therefore be inferred, considering the small amount of water indicated on heating in the closed tube, that the "volatile matter" consisted mainly of carbonic acid.

24. *Vein Graphite, var. Foliated.*

From Ticonderoga, State of New York.

Structure massive, compact, made up of narrow laminæ, interlocking each other at such an angle as to present an almost columnar appearance. Colour dark steel-grey. Lustre metallic. Specific gravity 2·2647 (containing 1·760 per cent. ash.) Heated in the closed tube gave off water sufficient to form a beady deposition.

The material employed for analysis was carefully selected ; its composition was found to be as follows :—

Carbon	97·422
Ash	1·760
Volatile matter	0·818
	100·000

Colour of the ash, brownish-red; a portion placed upon moist turmeric paper manifested an alkaline reaction.

The foreign mineral matter contained in this graphite consisted in part of calcite.

In the first of the two following tables the results of the foregoing analyses of vein graphites are given in a tabular form. The composition of the ash of the Canadian graphites 15, 16, 17 and 18, has, however, been omitted; for this information the readers attention is directed to the respective analysis of these graphites. In Table II. are embodied the results of the experiments on the relative combustibility of the graphites. Table showing composition of graphites.

TABLE I.—SHOWING THE COMPOSITION OF CANADIAN, CEYLON AND UNITED STATES GRAPHITE

Number.	Locality.	Specific Gravity.	Per Cent.		
			Volatile matter.	Carbon.	Ash.
15	CANADA, BUCKINGHAM. *Vein graphite, var. Foliated....*	2·2689	0·178	99 675	0·147
16	CANADA, BUCKINGHAM. *Vein graphite, var. Columnar ..*	2·2679	0·594	9[illegible]·626	1·780
17	CANADA, GRENVILLE. *Vein graphite, var. Foliated....*	2·2714	0·109	99·815	0·076
18	CANADA, GRENVILLE. *Vein graphite, var. Columnar ..*	2·2659	0·108	99·757	0·135
19	CEYLON. *Vein graphite, var. Columnar ...*	2·2671	0·158	99·792	0·050
20	CEYLON. *Vein graphite, var. Foliated....*	2·2664	0·108	99·679	0·213
21	CEYLON. *Vein graphite, var. Columnar ..*	2·2546	0·900	98·817	0·283
22	CEYLON. *Vein graphite, var. Foliated....*	2·2484	0·301	99·284	0·415
23	U. S., TICONDEROGA, N. Y. *Vein graphite, var. Foliated....*	2·2599	1·191	96·656	2·153
24	U. S., TICONDEROGA, N. Y. *Vein graphite, var. Foliated....*	2·2647	0·818	97·422	1·760

Remarks on the foregoing Table—The numbers in the column preceding that of the locality, correspond with those of the analyses of the various graphites : under these will be found a description of the graphite, and, in some instances, the composition of its ash.

Of Canadian vein graphites the foliated variety possesses the greatest freedom from foreign mineral matter, and is not unfrequently of very great purity : the specimen of which 17 is an analysis may be taken in illustration of this. In selecting the material for analysis, a trifling quantity of foreign mineral matter was separated; the amount, however, was so small that even had it not been excluded, it is questionable if the percentage of ash would have been thereby raised a tenth of a per cent., and this is inferred from the fact that a specimen taken from the same piece, and without any discrimination, gave only 0·098 per cent. ash. Analysis 15 will serve to show the purity not unfrequently attainable by a simple rough hand dressing. By rejection of such portions as contained the more prominent impurities, the ash in this sample was reduced to 0·195 per cent., whilst in the yet more carefully selected portion employed for analysis, it amounted to only 0·147 per cent. The true columnar variety is rarely so pure as the foliated; its structure being generally more or less permeated by earthy impurities. The specimen of which 16 is an analysis, and which was chosen from one of many as being apparently the purest, contained, as will be seen, even after having been very carefully selected, 1·78 per cent. ash.

Of the Ceylon graphites, 19 and 21 may be said to represent the composition of fair averages of the respective samples as received; whereas in the case of 20 and 22, although still very pure specimens, some slight discrimination was exercised in the selection of the material employed for analysis.

The specimens of Ticonderoga graphite both contained a good deal of foreign mineral matter, and the material employed in these experiments, and of which 23 and 24 are analysis, was very carefully selected.

TABLE II.—SHOWING THE RELATIVE COMBUSTIBILITY OF CANADIAN AND UNITED STATES GRAPHITE AS COMPARED WITH THAT OF CEYLON.

Table showing relative combustibility of graphite.

Number.	Locality.	Relative Combustibility.		
		Method I.	Method II.	Mean.
20	CEYLON. *Vein graphite, var. Foliated*.....	1·00	1·00	1·00
21	CEYLON *Vein graphite, var. Columnar*	1·02	1·00	1·01
22	CEYLON. *Vein graphite, var. Foliated*.....	0·98	1·01	0·99
19	CEYLON. *Vein graphite, var Columnar*.....	1·25	1·25	1·25
1	CANADA, BUCKINGHAM. *Disseminated—Scaly*	....	1·02	1·02
3	CANADA, BUCKINGHAM. *Disseminated—Scaly*.....	1·01	1·02	1·01
15	CANADA, BUCKINGHAM. *Vein graphite, var. Foliated*.....	0·99	1·01	1·00
16	CANADA, BUCKINGHAM. *Vein graphite, var. Columnar*	1·00	1·02	1·01
17	CANADA, GRENVILLE. *Vein graphite, var. Foliated*.....	1·01	1·03	1·02
18	CANADA, GRENVILLE. *Vein graphite, var. Columnar*	1·12	1·12	1·12
23	U. S., TICONDEROGA, N. Y. *Vein graphite, var. Foliated*.....	1·02	1·00	1·01
24	U. S., TICONDEROGA, N. Y. *Vein graphite, var. Foliated*.....	1·01	1·00	1·00

Remarks on the foregoing Table—The manner in which these experiments were conducted has been described at the commencement of this report, under "methods" at 5. The numbers in the column preceding that of the locality, and which agree with those in the corresponding column of Table I., accord with those of the analyses of the various graphites. Nos. 1 and 3 which do not there appear, here refer to the analyses of the "Disseminated graphite" from which the "dressed graphites," analyses 14 and 11, were prepared, portions of which latter were

specially purified for these experiments, in order to bring them into some accordance with the other graphites, as regarded percentage of ash. In selecting the standard, the choice lay between 20 and 22, for the reason however, that the latter was understood to be the most expensive, it was concluded that it would be scarcely likely to meet with such an extensive application in the manufacture of crucibles as the former, to which, in consequence, the preference was given. The figures given under method I. and II. are in both instances the mean of two closely concordant determinations; they represent the amounts of graphite burnt off as compared with 1·00 of that of the graphite employed as standard (Ceylon 20) when ignited under precisely identical conditions. In appearance the Ceylon graphites were, with one exception, undistinguishable from the Canadian, the exception being 19, the structure of which entirely differed from that of any of the Canadian specimens, the only one of the latter at all approaching it in this respect being 18, and this only in parts, the remainder of the structure being much coarser. As will be seen, these two specimens were the most combustible of the Ceylon and Canadian graphites. A specimen of Canadian graphite from Grenville, and closely resembling the Ceylon variety 22 in appearance, was unfortunately omitted from the experiments. There appeared to be some, if indeed it may not be said, a close connection between the combustibility of the graphite, and its resistance to mechanical division (pulverisation); those most difficult to pulverise being the least combustible.

Relative value of Canadian graphite as compared with that of Ceylon for the manufacture of black-lead crucibles.

From these experiments it will be seen that in respect to incombustibility the Canadian graphite may claim perfect equality with that of Ceylon; and that consequently—apart from any consideration of the proportion and nature of the associated foreign matter—it is in no wise inferior to the latter as a material for the manufacture of crucibles.

Prepared according to the present process, the "dressed graphite" (analyses 5 to 14 inc.,) obtained from the beds of the disseminated mineral (analyses 1 and 3) is apt to contain more or less carbonate of lime and oxide of iron; it has however been pointed out, experimentally, (analyses 12 and 14,) how readily these admit of removal by a very simple and inexpensive chemical treatment, leaving the graphite with a very small amount of ash, and that of a nature in no wise prejudicial to its application for the purpose here under consideration. That the graphite from this source, in itself compares favourably with that of Ceylon, will be seen from the above table, 1 and 3.

25. *Orthoclase.*

Analyses of orthoclase from Buckingham.

From the twenty-seventh lot of the sixth range of Buckingham.

The mode of occurrence of this felspar has been referred to under analysis 16. It was intimately associated with calcite and small quantities of an almost colourless translucent quartz.

Hardness 6. Specific gravity 2·5364. Colour white. Lustre vitreous. Translucent. Two distinct cleavage planes meeting at the angle 90°. Fracture uneven. Before the blowpipe in fine splinters it fuses (at about 5) on the edges to a semi-transparent vesicular glass.

The material employed for analysis was very carefully selected; after drying at 100° C. its composition was found to be as follows:—

Silica	64·140
Alumina	18·620
Sesquioxide of iron	0·374
Protoxide of manganese	trace
Lime	0·740
Magnesia	0·065
Potash	14·868
Soda	1·766
Loss by ignition	0·406
	100·979

Oxygen ratio of $RO : R_2O_3 : SiO_2 = 1 : 2·73 : 10·63$.

26. *Orthoclase.*

From the twenty-second lot of the seventh range of Buckingham.

It is the principal gangue of the greater number of the true veins of graphite in the Townships of Buckingham and Templeton. Authority, Mr. H. G. Vennor. The felspar was associated with a very small quantity of colourless translucent quartz.

Hardness slightly above 6. Specific gravity 2·5796. Colour pearl-grey. Lustre vitreous. Sub-transparent. Two distinct cleavage planes meeting at the angle 90°. Fracture uneven. Before the blowpipe in fine splinters it fuses (at about 5) on the edges to a semi-transparent vesicular glass.

The material employed for analysis was carefully selected; after drying at 100° C., it was found to contain:—

Analyses of orthoclase from Buckingham.

Silica	63·690
* * * * * *	
Potash	12·752
Soda	3·106

27. *Orthoclase.*

This felspar is the predominating constituent of the granitoid quartzo-felspathic rock occurring in connection with the vein of graphite on the twenty-seventh lot of the sixth range of Buckingham.

The rock is composed of orthoclase, small quantities of colourless, translucent quartz and dark olive-green pyroxene, with a little clove-brown, subtranslucent sphene and an occasional crystal of pale wine-red, subtranslucent zircon.

This feldspar has a hardness a little above 6. Specific gravity 2·5780. Colour pale violet-grey. Lustre vitreous. Subtransparent. Two distinct cleavage planes meeting at the angle 90°. Fracture uneven. Before the blowpipe in fine splinters it fuses (at about 5) on the edges to a semi-transparent vesicular glass. Carefully selected material dried at 100° C., gave :—

Silica	63·460
Alumina	18·780
Sesquioxide of iron	0·394
Protoxide of manganese	trace.
Lime	1·280
Magnesia	0·216
Potash	13·923
Soda	2·173
Loss by ignition	0·466
	100·692

Oxygen ratio of R O : $R_2 O_3$: $Si O_2$ = 1 : 2·62 : 10·02.